THE IIASA DATA COMMUNICATION NETWORK

J.H. Sexton

J. Page

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Introduction

This project, started in 1975, aims to connect together a number of computer centres at scientific research institutions in the member nations supporting IIASA.

IIASA -- an International Institute for Applied Systems Analysis

In order to understand the origins and goals of this network it is necessary to know something of the Institute and its functions.

IIASA was founded in 1972 and is currently supported by 17 National Member Organizations (NMOs), including the Academy of Sciences of the USSR and the National Academy of Sciences of the USA.

IIASA is an independent, non-governmental research institution which aims to explore major global issues which involve groups of nations, in an objective way using the methods of Systems Analysis. As an example, the scientific programme in 1977 included research projects in Energy, Food & Agriculture and Bio-Medical systems.

Scientists come to IIASA for relatively short periods ranging from a few weeks to one or two years. This flow of people constitutes a vehicle for the coordination of IIASA and NMO research, for the catalysis of parallel research and for the spread of information and results. It has led to the establishment of valuable links with national research institutes, universities, etc.

IIASA is a small institute and relies on the collaboration of the NMOs. Collaboration implies communication and because of the major role that the computer plays in modern systems analysis, this includes data-communication. It is for this reason that we have embarked on a joint programme to construct a computer network.

The fundamental feature of IIASA research is illustrated by Table 1 which shows, for European National Member Organizations only, the make-up of IIASA scientific staff in terms of man-months and numbers of scientists. The figures include all scientific staff members who have joined the Institute from the first arrivals in 1973 up to November 1976.

Table 1. Sources of IIASA scientists (European NMOs).

Country	Scientist Man-Months	No. of Scientists	Geographical Focus	% of Man-Months from Institutes at Focus
Austria	392	18	Vienna	97%
Bulgaria	76	3	Sofia	100%
CSSR	28	2	Bratislava	100%
FRG	268	12	Karlsruhe	50%
France	169	6	Paris	73%
GDR	102	5	Berlin	55%
Hungary	102	4	Budapest	100%
Italy	100	2	ISPRA	58%
Poland	127	6	Warsaw	100%
UK	161	10	London	71%
USSR	598	29	Moscow	88%

A comparison of the man-months and number of scientists columns points to the rather rapid turn-over of staff, while the last column shows that most of the staff-effort is contributed by institutes which are geographically concentrated in rather few locations.

It is on this basis that plans for the IIASA Network are being drawn up, and for the time being we are confining our attention to this European area.

The Bratislava Protocol

In December, 1975 the first of a series of meetings of centres involved in the IIASA Network took place in Bratislava. At that meeting the goals of the project were thoroughly discussed and an agreed protocol elaborated [CSN 10].

This protocol states that:

1. The main goals of the IIASA Network are:

   a) The communication and exchange of information between scientists involved in inhouse research and their counterparts in the NMOs and between national institutions.

   b) The development of the IIASA Network in order to realize systems in accordance with the requirements of participating national institutions, IIASA Projects and the general interest of IIASA.

   c) To work towards the standardization which will enable easier realization of national and international computer networks. This work to take into account the activities of CCITT, ISO and IFIP.

Each centre will devote manpower and resources to the Network which will be developed with IIASA's guidance.

Long before this meeting, starting in the early months of 1975 the groundwork for this project had been laid. By the summer of 1975 it had been decided to adopt the emerging ISO standard, HDLC, for the basic link protocol, and modifications had been worked out to provide symmetry for computer to computer connections [CSN 4.4]. It is interesting to note that this modification is essentially the same as that later adopted by ISO/TC97/SC6.

At the Bratislava meeting it was also decided to establish technical and management committees. Further meetings were arranged at roughly three monthly intervals. All the national institutions involved fund their own activities in the project, often at a higher level than the central team itself; the role of the central team at IIASA is more to provide a focus for joint initiatives and to coordinate and plan the cooperative activity as a whole, than to act as an international executive project management under authority delegated to it, funding network development from a central budget. From an organizational point of view therefore the project is quite unlike other international computer network developments such as the European Informatics Network (EIN) or EURONET of the European Economic Communities. Further, the collaborative nature of the project reflects a particular IIASA need: the mutual interchange of people, information and ideas in furtherance of a project task implies a rather sophisticated level of physical communications to support it. A scientist at IIASA may wish to use software resident on his home institute computer to solve a particular problem: the obvious means of doing so is to provide a facility for interrogating that computer from IIASA. Scientists at the national institute level may need to use software or files on the IIASA computer in the course of a joint project. Particular instances of meeting such needs through the IIASA computer network may be quoted: for example, the IIASA Water Resources Project and institutes in Poland active in the same area of research will make use of the network to exchange data, and it is planned to extend this into a three-way information and data exchange with access to hydrological data on computers located in Italy, using the Pisa node of the IIASA Network. Improvization of such facilities as the need arises is technically possible, but expensive in terms of renting facilities and in the diversion of manpower to improvise connections, either short-term leased lines or satisfactory dial-up arrangements. In any case, experience shows that the percentage of success in arranging ad hoc facilities of this kind is in general low. The concept of a IIASA computer network as a collaborative project between national institutions and IIASA itself is therefore, at least in part, to be regarded as the provision of a special type of service necessary to other Project tasks in IIASA and the National Member Institutes.

INTERNETWORKING

The need is not limited to the provision of individual facilities as they become necessary: the concept of the network also embraces an element of research and development. Granted that many countries now possess, or are developing their scientific computer networks, and while these use some common technical standards, they are unlikely to be totally compatible with each other, i.e. totally transparent to all potential users. Therefore, in the design of the IIASA network considerable attention has been paid to the "gateway" role, by which the IIASA Network could act as a link between national networks. The ideal would be to make internetworking so transparent that a particular computing task might be split up into component parts, each of which is best done by a particular hardware/software combination on different computers, the final result being delivered to the user at his own terminal. Totally distributed computing in this fashion is, however, not yet fully practicable on an operational level: considerable effort is being devoted to the problem in several computer networks.

The IIASA network is not, however, an exercise in advanced computer-telecommunications technology or a basic research project in network design. Research is carried out to the extent necessary to solve the practical problems of providing interconnections between facilities (computer and other networks) where such interconnections could meet user needs.

The basic concept can be summarised thus: the broader IIASA community, which includes not only IIASA staff but scientists in National Member institutions, is in fact an intellectual network; the effective operation of which demands a sophisticated and permanent means of transport of data and information. This intellectual network therefore requires a physical computer network to make it operate. Because the IIASA computer network is itself a collaborative project, carried out within the same constraints and operational conditions as any other IIASA project, it cannot be viewed as a service to be centrally funded and managed. It is thus itself an experiment in the organization of a collaborative project in which aims and means to achieve them are agreed by all parties concerned.

PARTICIPATION

Some fifteen institutes, in addition to IIASA, have so far committed themselves to active participation in the network, for example to provide host or node facilities and/or the development of network systems and software. While the IIASA Computer Science Project has acted as initiator and coordinator, the work of network design and implementation is essentially a collaborative activity, in which each centre contributes hardware, computer time and manpower to an agreed work programme. In fact, some 60 scientists in the participating institutes are involved in the development of the network.

Further, certain institutes have already made provision for leased line connection to IIASA, and it is expected that this part of the communications subnet will be in operation by the end of 1977. These connections are from IIASA to:-

Pisa

Budapest

Bratislava.

These connections are in addition to the present leased circuit between IIASA and Vienna. Participation in the design of the IIASA Network is however on a much wider basis than these physical connections would indicate. A large number of institutes have expressed their interest in the Network; these institutes take part in the regular planning meetings, together with observers from other network organizations, such as Cyclades and EIN, and thus contribute to the design work. At a fourth meeting of the management and technical committees for the IIASA Network, held in Laxenburg, in November, 1976, some 21 organisations or institutes were represented.

By the end of 1976, the following institutes had entered into commitments to participate in the network:-

Austria

Vienna: Technical University

CSSR

Bratislava: The Computing Research Center

GDR

Berlin: Center for Computing Technology of the Academy of Sciences of the DDR

Hungary

Budapest: The Computer and Automation Institute

Italy

Pisa: Computer Institute of the National Research Council (CNUCE)

The Institute for Data Processing

Poland

Warsaw: The Institute of Communication

The Institute for Basic Research in Informatics of the Polish Academy of Sciences

The Institute for Systems Research of the Polish Academy of Sciences

The Institute for Meteorology and Water Management

The Center for Scientific Information of the Polish Academy of Sciences

USSR

Moscow: The Institute of Electronic Control Machines

The Institute of Control Sciences

Kiev: The Cybernetics Institute

Riga: Institute of Electronics and Computing Techniques of the Latvian Academy of Sciences.

Other centres in other countries have expressed an intention to participate in the network, for example, the Bulgarian Institute for Computing Techniques, Sofia, and the Regional Computing Centre at the University of Kaiserslautern, Federal Republic of Germany.

NETWORK TOPOLOGY

As the network is in the stage of active implementation of hardware and software, a topological diagram is subject to rapid changes: the network at present consists of eight nodes in varying stages of implementation; some eleven host machines are currently planned for connection to these nodes. The diagram in Figure 1 represents the network as it is now configured.

It should be noted that at the present time many connections between nodes are temporary (in the sense of operator-connected or dialled circuits). The present plan for permanent links is shown in CSN 027.

SOME LANDMARKS IN DEVELOPMENT OF THE IIASA NETWORK

While a few experiments to test the feasibility of data transfer, computer-computer and terminal-computer started in late 1974, the concept of a IIASA Network really began with discussions with computer centres in Czechoslovakia and Hungary in early 1975. By March of that year, it was possible to make a considered proposal for the project, based on the principle that each centre would jointly participate in network development covering its own costs. In this original proposal, it was proposed to establish nodes at IIASA, Bratislava and Budapest, using minicomputers already in service at these locations. Already at this early stage, further expansion of the network was envisaged, but also the provision of gateway facilities to other networks. The proposal was discussed at a meeting held in Budapest in March, 1975, and agreement was reached to jointly develop a network on the lines of the initial proposal.

Bratislava Meeting, December 1975

During the second half of 1975, the original plans were expanded and elaborated, and experiments continued on data transfer. In addition to the Computer and Automation Institute (Budapest), the Computing Research Centre (Bratislava), and IIASA, the Institute of Control Sciences (Moscow), the Cybernetics Institute (Kiev), and the Technical University (Vienna) indicated their interest in joining the project, and the Bulgarian and Polish Academies of Sciences also expressed their willingness to collaborate in the Project. At this stage, it was possible to suggest certain possible basic network configurations. At this stage also, surveys of available hardware resources, programming languages, etc. were undertaken. The problems of a common language, a common line protocol and the ultimate need for higher level host-host protocols were also under examination. All these activities culminated in discussions and decisions taken at a meeting for representatives of National Member Organisations, and members of national institutes interested in collaboration in the

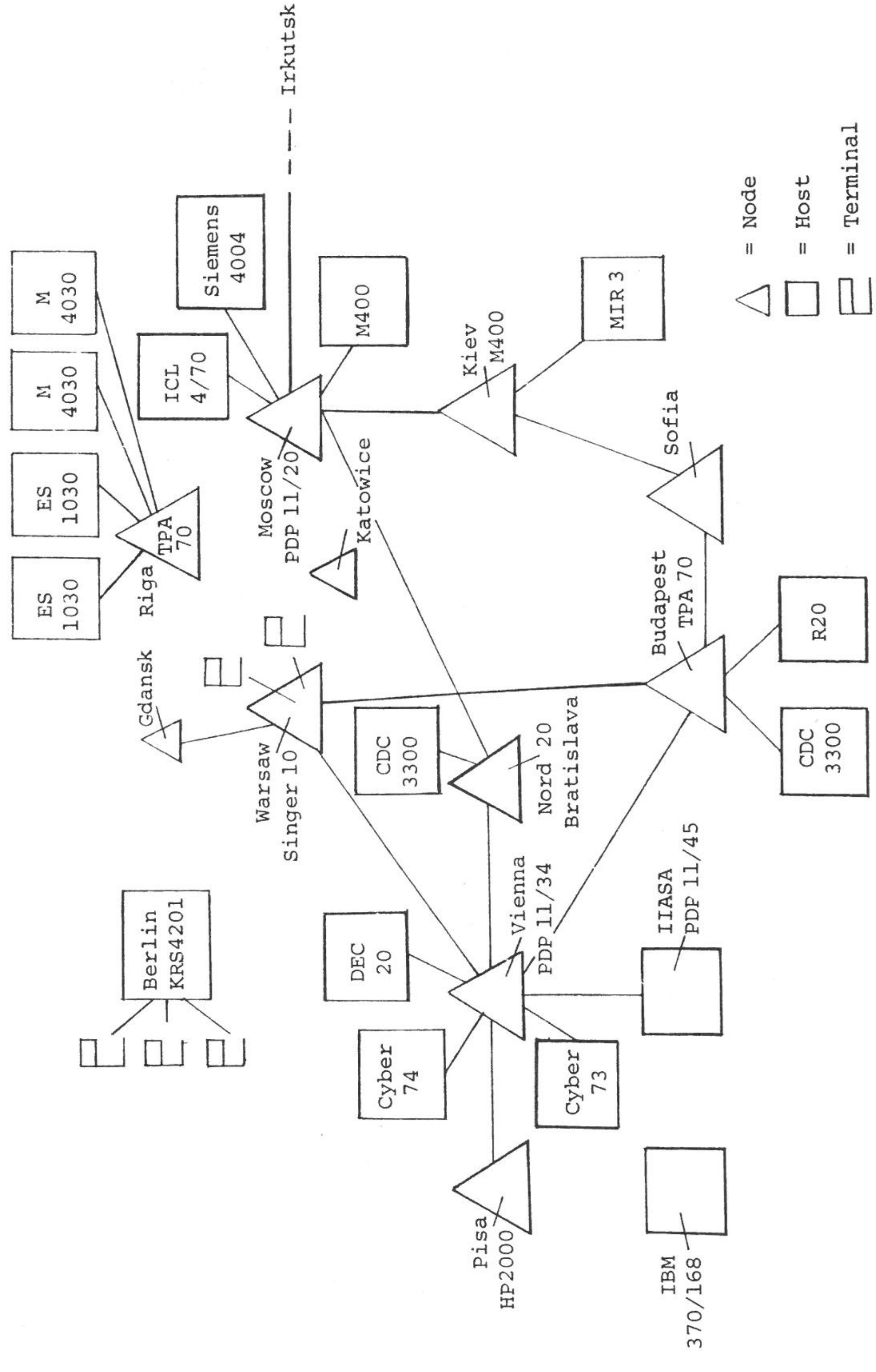
Irkutsk
Siemens 4004
M 4030
M 4030
ES 1030
ES 1030
Riga TPA 70
ICL 4/70
M400
Moscow PDP 11/20
Katowice
Kiev M400
MIR 3
Sofia
Budapest TPA 70
R20
CDC 3300
Gdansk
Warsaw Singer 10
CDC 3300
Nord 20 Bratislava
Berlin KRS4201
DEC 20
Vienna PDP 11/34
IIASA PDP 11/45
Cyber 74
Cyber 73
Pisa HP2000
IBM 370/168
= Node
= Host
= Terminal

Figure 1

project, which was held at Bratislava on 17 - 18 December, 1975. The results of that meeting included a precise definition of the aims of the network, the various forms of participation in it, including establishing nodes and links to other nodes, terminal to computer communication with the network and involvement in development of network software. It was also agreed that participating institutes or National Member Organisations would be responsible for the financing of their part of the network development. Thus, it was not necessary to establish a common fund for this purpose. An approximate time schedule for initial development was also prepared, and, on the management side, it was decided to establish a steering committee to coordinate the joint activities of the participating institutes, and a technical committee to elaborate and define technical requirements and specifications: these committees were to meet regularly at about 3-monthly intervals.

Budapest Meeting, 5 - 7 April, 1976

At this meeting, it was possible for the five centres now participating in the project to report substantial progress. The Budapest centre had developed a node operating system on their TPA 70; the Moscow centre had developed an experimental network, and had also conducted several further data transfer tests with IIASA, and the Vienna and Warsaw centres were able to announce funding for nodal minicomputers. The NORD 20 minicomputer destined to form the Bratislava node had been experimentally installed at IIASA to verify the operation of the variant of the HDLC line protocol developed for the network by IIASA. Other papers presented and discussed included an initial proposal for packet switching, and a proposal for rationalising the approach to provision of communication facilities between the participating centres: the necessity to involve the PTTs in planning the communications network was emphasised. The need to study user services was also stressed.

While the Budapest meeting established priorities for future technical planning, for example, in the shape of the development and elaboration of a packet switching proposal, the main operational result was the decision to standardise on the IIASA variant of the HDLC line protocol, and the allocation of further development work in this area on the part of the network as a whole, to the Budapest centre. The sequence in which one centre initiates an idea, elaborates it in discussion with other centres, carries out initial development and finally, passes further development and maintenance to another centre in the network, well illustrates the special collaborative nature of the IIASA network project.

Warsaw Meeting, 31 May - 4 June, 1976

At this meeting, a revised and elaborated proposal on packet switching was presented. This was generally agreed as a basis for implementation subject to later revision, in the light of experience. It was also recognized that a virtual call service would also be necessary, but this was seen as a component of the end-to-end protocol necessary for network users. This was accepted as an important priority area for future study. User aspects of the network were also an important topic. Use of the network by national centres participating in the IIASA Water Resources Project was noted as a major step forward in the practical application of the network as a service to users.

Thus, by September, 1976, most of the remaining problems in network technology and in preparing for operational use of the network were either in the stage in which elaborated proposals had been made or were under intensive study. Bulgaria had expressed its intention to join the network and a draft agreement with the CNR Italy for interconnection of the RPC NET and IIASA Network through a node in Pisa had been prepared. The German Democratic Republic had also expressed its intention to join the network. The Technical University, Vienna, had confirmed its intention to provide the hardware for a node in the IIASA Network and to connect this with the Austrian inter-university computing network (ACON).

Laxenburg Meeting, 4 - 5 November, 1976

At this meeting, results of studies on the higher level (end-to-end) protocols were discussed and the current status of the network and communications planning were reviewed, and papers on terminal connection problems considered. It was decided to adopt the X25 virtual call interface, and to devise a host-to-host protocol to suit this procedure for connecting hosts with the communications network. Progress in connecting national networks, e.g. the RPC network in Italy, was reviewed, and the University Computing Centre at Kaiserslautern (FRG) announced that it proposed to join the network: it was already operating a local homogeneous network of IBM computers. Funding of the connection to IIASA was being negotiated.

THE PATTERN OF NETWORK DEVELOPMENT

Network development has proceeded along lines clearly indicated by the statement of objectives agreed in December, 1975. These objectives implied that the design and implementation work would essentially be oriented towards the provision of a scientific communications facility as a collaborative exercise between a number of independent institutions;

the objective was not to engage in network design for its own sake, nor to undertake advanced research in computer telecommunications technology. Development work has in fact been limited to that necessary for the operational needs of each collaborating partner. In reviewing the development of the Network, three interwoven themes may be distinguished:-

(i) minimum constraints to be imposed on Host computers;

(ii) minimization of extra costs to participating institutes in respect of special communications and other hardware;

(iii) maximum use of existing standards where these may be directly applied, associated with collaborative development of detailed standards or procedures where necessary.

Bearing in mind the great diversity of Host computers in the national institutes associated with the IIASA Network, a network in which communications procedures imposed constraints on the type of computer which could be attached to it, is clearly totally incompatible with the overall goals of the project. In consequence it was necessary to adopt a design strategy in which as many of the communications facilities as possible are independent of Hosts and in any case, Host operating systems should not have to be modified to comply with network standards.

Secondly, the need to make use of existing hardware and to minimise cost to the participating centres, was bound to conflict with the technical requirements for simple and optimum solutions to the main design problems. For example, it is clearly easier to implement a network in which all the node machines are identical and this has been the practice in all other computer networks. For our network, it would not have been practicable to insist that all participating centres purchased new hardware, and in fact, the network as it is now being implemented will include at least three types of minicomputer node machines.

Thirdly, with respect to standardization problems, there are two aspects to be considered. While there must clearly be internal standards agreed by all participating centes on the basic protocols, agreed international standards should be adopted as far as possible. This is necessary if one of the prime aims of the network is to be met, i.e. that it should provide gateways between national networks, and also make use of existing or developing international networking facilities. Both requirements conflict to some extent with the other two elements of design strategy. For example, the recommended line protocol for the IIASA Network (HDLC) may not be able to be adopted by at least one national network due to be connected to the system.

DATA TRANSMISSION MODES AND RATES

For satisfactory operation of the network, data transmission rates of a minimum of 2,400 bits per second in synchronous mode is necessary. To achieve these speeds would require leased circuits; either four-wire operating in full duplex or two-wire (half-duplex) circuits, if suitable modems are installed, and the slight reduction in overall two-way transmission speeds owing to the finite turnaround time of the modem can be accepted. Higher speeds up to 9,600 b/s could probably be obtained over conditioned leased circuits with more expensive modems. For the initial experimental phase of the network, taking into account the fact that no centre could finance leasing lines which could hardly be utilised at more than a percent or two of overall capacity, it was decided to use the public switched telephone network making the connections either manually or by dial-up where this was possible. While for some connections, it was possible to transfer data at 600 or 1200 bits per second, for others, this was only successful at 300 b/s. While too slow for file transfer operations in a fully operational network, this has permitted some valuable experience to be gained at minimum cost. Nevertheless, it is clear that for the communications sub-net at least, high-speed leased lines must be provided and the problem is how to meet the heavy costs involved. Line charges are roughly proportional to distance up to about 400 km. If lines are used more than 4 hours/day, then a leased line is cheaper than dial-up and of course, avoids the sources of noise and difficulty of establishing connection present with normal dial-up service.

Aside from the problems of the cost of leasing lines in the initial experimental period, some centres have not yet been able to install the necessary interfaces for synchronous communication, and so, during the experimental period asynchronous (TTY compatible) transmission modes have been the rule. This has enabled the participation of two centres which could otherwise not have become involved with the experimental work in 1975-1976: here, also, the technical optimum solution has been (temporarily) abandoned in favour of one which is more in the spirit of the overall concept.

However, the connections made in 1977 to Pisa, Bratislava and Moscow are on the basis of high speed leased circuits operated in synchronous mode. The line cost problem is not easy to overcome, but in some cases, the institutes concerned have been able to finance their connections from national research budgets, but another suggestion is that the PTTs might be invited to lend the network suitable circuits without charge for the development period, on the lines of the arrangements made in the CYCLADES network in France.

PROTOCOLS

The initial emphasis in design of the IIASA Network was on the lower level protocols. An early study of possible data link control procedures showed that there were two main possibilities, HDLC (High level Data Link Control procedure) as described in ISO TC 97/DIS 3309 and TC 97/SC 6/1005, and IBM BSC (Binary Synchronous Control). HDLC is a relatively new and as yet not fully defined standard. But it has been adopted for use within the European Informatics Network (EIN) and the Canadian DATAPAC network. At the time of the study, HDLC had also been proposed for the CYCLADES network, and a version of HDLC was chosen as the IIASA standard on the grounds of its general suitability and in conformity with the principle that where a satisfactory international standard exists, it should be adopted.

Nevertheless, because HDLC is not a fully defined and detailed standard, certain difficulties remained. The EIN version was considered to be unsuitable; further, as HDLC is intended for synchronous working and some of the IIASA links must, at least for the experimental period, operate asynchronously, some changes were necessary. These changes are described in CSN 004, the definitive description of the IIASA version. The IIASA version of HDLC permits both asynchronous and synchronous operation, but is sufficiently flexible to allow changes in detail when fully synchronous working is possible over the network as a whole.

The impossibility of total standardization in detail between all centres participating in the project, and the national networks of which they already are a part, is illustrated by the connection with the Italian RPC network through the node at Pisa. The RPC network, being a network of IBM computers, employs the IBM BSC protocol. Because it is impracticable to expect that network to change its standard, a solution was found by means of an interface at the Pisa node. Such solutions are not technically ideal, but where necessary, design compromises of this nature must be accepted as the only way to enable the network to fulfill its objectives.

NODAL SOFTWARE

Software for the network nodes is required for three functions:

- packet transmission;
- routing and associated functions;
- monitoring, including testing facilities in the implementation phase.

As already noted, the overall design strategy required that the network could operate with different types of minicomputer nodal machines. Inevitably, this meant that software could not be entirely interchangeable because different types of operating systems would be used. However, software development should be coordinated, and based on the modular principle, in order to achieve maximum transportability. The Budapest centre took the lead early on in developing nodal software, based on the Node Task Activating (NOTA) operating system and Dynamic Memory Management (DMM) software. The total package is described by P. Darvas and A. Labadi in CSN 016. While some centres may wish to develop their own nodal software, the "transportable module" concept should result in a fair degree of standardization between the software used in the three types of minicomputers forming the network nodes.

PACKET SWITCHING

The general reasons for adopting packet switching as the standard for the network have been discussed in CSN 1, 2 and 3. However, design of a detailed system conforming to the general design strategy noted earlier is difficult because of a lack of agreed international standards. The basic concept adopted is that the transport of messages throughout the communications network should be in the form of a datagram service, i.e. messages should be divided into packets and reconstituted outside the communication subnet: ordering of packets into their correct sequence would not be a part of this function. Within a datagram service, the main standard required is that for packet formats, but there was not a fully defined and agreed international standard. The IFIP International Network Working Group (TC6/WG/6.1) had suggested a format known as the D standard, which had been adopted by EIN and CYCLADES, so that in principle it provided the possibility for IIASA of standardisation with other networks. The IIASA version, which has now been agreed by other participating centres is described in detail in CSN 013.2. It has been implemented at IIASA and in Budapest.

END-TO-END PROTOCOLS

In this difficult subject area, which is of considerable importance in the case of a heterogeneous network of host computers used for scientific research purposes, the problem is complicated by the fact that there are two international standards based on a widely differing concept of the requirements for overall host-to-host or terminal-to-host communications. The two standards are the X25 proposed CCITT standard for a virtual call service, and the standard end-to-end protocol in INWG 96 proposed by IFIP Working Group 6.1. The first of these has been put forward by the carrier and PTT representatives in CCITT, and is more in the nature of a definition of a service to be provided, without reference to the internal mechanism by which it is provided, than protocol defining functions and how they are to be carried out. The IFIP proposal which is likely to be adopted as an ISO standard has been developed from the experience gained by experimental networks, and involves the datagram concept. The difference between these two standards, in terms of the requirements of the IIASA Network, have been analysed by J. Sexton in CSN 021, by K. Odolak, A. Zolotucho and R. Kujawa in CSN 029, and at the Second European Users' Workshop, reported in CSN 028. It is clear that the X25 standard does not provide the facilities desirable in an end-to-end protocol. On the other hand, several of the host computer centres to be attached to the IIASA Network wish to implement X25, if only because they are part of a PTT system. The papers referenced discuss the possibility of a combination of elements of the two systems so that all hosts, whether using X25 or INWG 96, could communicate with each other.

Studies of a IIASA end-to-end protocol are by no means complete, but the difficulty mentioned above well illustrates the particular nature of the kinds of design compromises necessary. It would be simpler to adopt a single standard, probably INWG 96, and require all hosts on the network to conform to it. To adopt the X25 virtual call procedure would require the development of an end-to-end protocol which could be superimposed upon it. Therefore, effort must be expended in planning a compromise solution in which no host is excluded, all the important end-to-end requirements are met, and the software requirements (and the storage needs) should be kept to a reasonable minimum.

FUTURE PLANS

The year 1977 has seen the formal completion of the experimental phase of the network, with the setting up of the first dedicated links to Pisa, Bratislava and Moscow and with communications and packet-switching software implemented. The actual commissioning of the communications sub-net, in its first operational configuration will take much effort: it is certain that a working-up period will be necessary in which testing and trouble-shooting will require intensive activity on the part of all the centres maintaining nodes.

It would moreover be unrealistic to suppose that by December, 1977 a network complete in all its facilities, even on a four-node basis, will emerge in a fully-operational state. Account must be taken of the differing stages of implementation which the collaborating centres can reach during 1977, which in turn depends on the amount of effort they are able to deploy on the equipment situation and of course on financial resources. As a minimum for the first operational stage in a fully packet-switched mode, all centres providing nodes of the sub-net must have implemented HDLC and the packet-switching software, and host (or host interfaces) must have implemented higher-level protocols to the extent that file transfer can take place and terminal access to other hosts is possible. This part may not be reached by all centres by the end of the year: in which case communications between IIASA and external hosts may be on a hybrid basis temporarily, with some communications going via the network and others on a point-to-point basis.

Therefore, 1978 will not see a static configuration with an even level of implementation of network facilities overall, and a steady and uniform pace of new developments, e.g., in high-level protocols. Instead, the most probable scenario for 1978 involves progressive but not necessarily even levels of development of the sub-net, coupled with expansions, new hosts being added, as communications and host-to-host software is implemented. This will have considerable repercussions on the operation of the network, and on the necessary management structure. From an internal IIASA point of view, the project as a task of the Computer Science group, is one to be completed at the end of 1977.

Serving the Users

Aside from the technical problems of commissioning, extending and developing the network, it will be necessary to give increasing emphasis on discovering and meeting user needs and promoting the effective use of the network generally. The key concept of the IIASA network as a tool for IIASA scientists and a mechanism to further collaborative research, both between IIASA and NMO Institutes and between Institutes in different NMO's, has already been stressed. Although particular needs in the areas of the water resources, energy and global modelling research have already been identified, the concept will not become a day-to-day reality solely as the result of providing the physical facility represented by a working communications sub-net connecting a number of hosts. It is the experience in other networks that use will only grow slowly if individual potential users are not made aware of what the network can do for them, and are not actively helped to use it. It can also be expected that many potential users will not be able to express their requirements precisely, because they will be unaware of how the network could help them.

Clearly, in a service and user-oriented environment, a dynamic policy for network management and operations will be required, and attention has already been given to this by IIASA and the Management Committee: the emphasis in project management and coordination is likely to pass from the purely technical problems to service functions in 1977-78. While the shape of future activities in this area is still at an early discussion stage, planning for actual operations will be required in the following respects:-

Sub-network Operations. At a rather early stage in the operational phase, it will be necessary to implement some form of monitoring and central function for the communications sub-network, so that malfunctions can be detected, diagnosed and corrected. The packet-switching software now being implemented makes this possible, but this responsibility must be allocated to a single centre: manpower and other resources will be necessary.

Resources Inventory and Management. Users will need an accurate, detailed and up-to-date inventory of host resources (hardware and software) available over the network. For example, it is necessary for a user not only to know details as to hardware and software configurations of the hosts he may wish to use, but also to be informed of files available to him, scheduling times, arrangements for access, host charges, etc. Such a system implies much coordinated effort on the part of host centres and the network management, and has proved a stumbling block in other networks with a much more monolithic structure than is possible in a collaborative project such as the IIASA network. On another level, it may be necessary to provide more general information about available resoruces to potential users so that scientists become aware of the possibilities which the network can offer. All this requires considerable effort and the allocation of financial and manpower resources, both centrally and locally within each participating institute. The problem of matching user needs, which may not be explicit, with resources available on the network could ideally imply a type of consultancy service.

All these questions of interfacing users with the network will not be solved within the first few months of operation, and the degree to which they can be solved will depend on the financial and on other means which the future management of the network can deploy. They can however, be taken as representative of the kinds of operational problems which will preoccupy IIASA and the other participating centres from 1977 onwards, and for which the network management as it finally evolves must be structured.

List of Computer Science Network Papers (CSN)

CSN 001	A Proposal for the Development of Computer Networking Facilities at IIASA (J.H. Sexton, March, 1975)
CSN 002	IIASA Network Project (J.H. Sexton, July, 1975)
CSN 003	IIASA Data Communication Network (J.H. Sexton, Spt. 1975)
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CSN 007.2	NOTA (P. Darvas & A. Labadi, Hungary)
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CSN 010	Protocol for the Meeting held at CRC, Bratislava (17. Dec. 1975)
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CSN 012	IIASA Computer Network Communication System, Design Manual, Volume 1, (A. Radziminski, March 1976)
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CSN 014	Networking Activities in Austria - a Joint Project between IIASA and the Inter-university Computer Centre Vienna (H. Bodenseher)
CSN 015	Problems in the Design of an IIASA End- End Protocol (L. Csaba, May 1976)

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